

REMARKS

Applicants respectfully request reconsideration of the present application in view of the foregoing amendments and for the reasons that follow.

I. Status of the Claims

No claims are amended or cancelled. After entry of this communication, claims 57-60, 62-76, and 79-80 are pending.

II. Claim Rejections – 35 U.S.C. § 103

a. Claims 57-59, 75 and 79 are rejected under 35 U.S.C. § 103(a) as allegedly unpatentable over Wu et al., (*Adv. Mater.* 14(1), (2002), pp 64-67). The Office action improperly relies on the proposition that “... where the only difference between the prior art and the claims [is] a recitation of the relative dimensions of the claimed device and a device having the claimed relative dimension [the claimed device] would not perform differently than the prior art device...” to maintain the obviousness rejection. See Office action at pages 2 and 4.

Applicants respectfully traverse this rejection.

The claimed invention is directed to a substrate comprising a plurality of carbon nanosheets. Each of the plurality of carbon nanosheet has a thickness of 2 nm or less and the plurality of carbon nanosheets are aligned and stand on their edges roughly vertical to the substrate.

In asserting that there is no difference between Wu’s carbon nanowalls that have a thickness of 10 nm or less and the claimed carbon nanosheets (CNS) having a thickness of 2 nm or less, the Office has failed to consider

(i) that the skilled artisan would not have understood Wu to teach nanowalls having the recited thickness, and

(ii) evidence demonstrating a significant differences in the physical and chemical properties of a carbon nanosheet having a thickness of 2 nanometers or less as claimed and the disclosed carbon nanowalls having a thickness of 10 nm.

Regarding (i), Wu clearly was in possession of analytical techniques that allowed him to measure structures on the nanometric scale. For instance Wu illustrates in Figure 2F an SEM image

of a nanowall which has a thickness of 10 nm. See caption under Figure 2, page 66 of the Wu article. The scale bar accompanying figure 2F, moreover, confirms that the nanowall shown in this figure has a thickness of 10 nm.

There are other reasons to support Applicants' proposition that Wu's nanowalls do not have the recited thickness of 2 nm or less. Raman spectroscopy is a non-destructive analytical tool often used for structural characterization of materials. As set forth in the present specification, Raman spectroscopy of nanosheets (Figure 3) having a thickness of 2 nm or less shows three well resolved peaks at 228, 355 and 864 cm^{-1} . In contrast, Raman spectral characterization of carbon nanoflakes which have a thickness greater than 2 nm, gave a spectral signature having the following peaks: two strong peaks at 1350 cm^{-1} (D peak) and 1580 cm^{-1} (G peak), and a less intense peak seen as a shoulder to the G peak at 1620 cm^{-1} . See Figure 1 of the specification as filed.

The Raman spectral signature of Wu's nanowalls shows four peaks with frequencies at 220, 1335, 1584 and 1617 cm^{-1} . The skilled artisan would have readily recognized that the disclosed peak frequencies conform to frequencies for Raman spectral peaks for carbon nanoflakes having a thickness greater than 2 nm with the 220 cm^{-1} peak due to folding of the top of Wu's nanowall.

Stated differently, Raman analysis of Wu's nanowalls do not show peaks that are characteristic for carbon nanostructures that have a thickness of 2 nm or less. The comparison of the spectral data provides compelling evidence that the claimed nanosheets having a thickness of 2 nm or less are structurally different from those disclosed by Wu.

There are other secondary factors that support the patentability of the inventive nanosheets. For instance, as stated above in (ii), the Office Action fails to consider that physical and/or chemical properties of nanomaterials depend on their dimensions, and even subtle changes such as a change in thickness by the addition of an extra layer of graphene in a nanosheet would alter the properties of the modified nanostructure. In the present Office Action, the obviousness rejection is supported by generic statements asserting that the thickness of Wu's nanowall (10 nm), overlaps the claimed thickness range of 2 nm or less. Therefore, the Office action concludes that the claimed nanostructures should possess the same properties and should not perform differently than nanowalls disclosed by Wu.

This conclusion is simply incorrect, and Applicants note that the 2010 Nobel Prize in Physics was awarded for the isolation and characterization of single-layer graphene. The physical properties

of carbon nanostructures are markedly different for single-layer graphene and nanostructures comprising a few layers of graphene relative to carbon structures containing many layers, such as 10 nm thick carbon nanowalls. For example, in field emission, thin edges provide for the packing of more electric field lines at the edge so that the local electric field and therefore the emission of electrons is significantly enhanced. This is a basic aspect of the Fowler Nordheim theory and was the objective of the research that led to the claimed invention. .

In a supplemental information disclosure statement (IDS) accompanying this communication, Applicants attach three published articles (Wilson. M., *Physics Today*, (2006), pp. 21-23 (**D1**); Geim *et. al.*, *Physics Today*, (2007), pp. 35-41 (**D2**); and Rao *et al.*, *Sci. Technol. Adv. Mater.* 11 (2010) 054502 (15pp) (**D3**)), as well as a summary of the 2010 Nobel Prize for Physics (**D4**) issued by the Royal Swedish Academy of Sciences, all of which support the proposition that there are measurable differences in the physical properties of nanosheets containing a single or two layers of graphene, as compared to a 10 nm sheet of graphite having multiple stacked layers of graphene.

As set forth in these articles, graphene is a single, one atom-thick sheet of carbon atoms arranged in a honeycomb lattice. D1 states that graphene is remarkably stable, inert and crystalline. These properties allow graphene to carry huge current densities, roughly two order of magnitude greater than copper. See D1, middle column, page 21.

Graphene also exhibits other properties with applications, for example, in the electronics, catalysis, and fuel cell fields. For instance, graphene is optically transparent (see D4 at page 4), and because a graphene layer has very small thickness the gap between the valence band and conduction band in graphene shrinks to a single point allowing electrons to behave as massless particles (e.g., like photons) in graphene. That is, for graphene the mass of the electron no longer has an effect on their velocity, allowing graphene to carry very large current densities at extremely high speeds. See D1, left column at page 22.

In contrast, graphite is made up of hexagonal carbon sheets stacked on top of each other. The valence and conduction bands of graphite do not coalesce to a single point as in graphene. Moreover, because of its thickness the transport of electrons in graphite depends at least in part on the interaction of electrons with graphite's lattice. The extent of electron-lattice interaction is dictated by the mass of the electron. As a result of these differences and the presence of a gap between valence and conduction bands, electrons in graphite have lower velocities.

Based on these differences in physical properties of graphene and graphite, it is clear that Wu's nanowalls having a thickness of 10 nm would not exhibit the same physical properties as nanosheets having a thickness of 2 nm or less as claimed.

For at least the above reasons, the claimed nanosheets are patentable in view of Wu and Applicants respectfully request the PTO to withdraw this rejection.

b. Claim 60 is rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over Wu et al., as applied to claims 57-59, 75 and 79 above, and further in view of *Carbon*, (39) 2001 505-514 ("Peigney").

The PTO states that Wu teaches carbon nanowalls with lateral dimensions between 1 to 2 micrometers, which the PTO states falls within the claimed range. Office action at page 5. The PTO further states that Wu's nanowall has the same specific surface area (SSA) as the claimed nanosheet because Wu's nanowall is made of the same material as the claimed nanosheet. Office action at page 6.

Peigney is cited to teach "carbon materials...[that] have a specific surface area within the range recited in dependent claim 60.

As stated above, Wu's nanowalls may be made of carbon, but they are not the same as the claimed carbon nanosheets. Wu's nanowalls comprise multiple layers of graphene that are stacked on top of each other to form the **thicker** nanowall structure. As stated above the properties of a nanostructure with many layers are different from those of a nanosheet having a thickness of 2 nm or less.

Moreover, Peigney relied on to inform the skilled artisan of the SSA of carbon nanostructures clearly shows that the SSA of its carbon nanotubes (CNT) decreases as more overlapping layers are added to a single-walled CNT. That is, Figure 2 illustrates that an inverse correlation exists between the SSA of a CNT and its diameter. Stated differently, the SSA of a CNT decreases as its diameter increases.

Again, Applicants state that Wu does not teach the inventive nanosheets and the mere disclosure for the SSA of a single walled CNT in Peigney fails to remedy the deficiencies in Wu. Thus, the obviousness rejection is improper and Applicants respectfully request the PTO to withdraw the rejection.

c. Claims 62-64, 76 and 80 are rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over Wu et al., in view of Peigney.

Claim 62 recites a composition comprising a plurality of carbon nanoflakes having a specific surface area between $1000 \text{ m}^2/\text{g}$ and $2600 \text{ m}^2/\text{g}$, wherein the carbon nanoflakes are aligned, freestanding and stand on their edges roughly vertical to a substrate. As stated above, Wu does not teach or suggest the inventive nanosheets and Peigney fails to remedy the deficiencies in Wu.

In summary, the skilled artisan, cognizant of the teachings of Wu and Peigney, would have found neither guidance nor motivation in the cited references for arriving at the claimed invention.

Accordingly, all pending claims are patentable and Applicants respectfully request the PTO withdraw the obviousness rejections.

CONCLUSION

The above remarks address the PTO's concerns on patentability. Therefore, Applicants respectfully request the PTO to provide an early indication to this effect.

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The Commissioner is hereby authorized to charge any additional fees which may be required regarding this application under 37 C.F.R. §§ 1.16-1.17, or credit any overpayment, to Deposit Account No. 19-0741. Should no proper payment be enclosed herewith, then the Commissioner is authorized to charge the unpaid amount to the same deposit account. If any extensions of time are needed for timely acceptance of papers submitted herewith, Applicants hereby petition for such extension under 37 C.F.R. §1.136 and authorizes payment of any such extensions fees to the same deposit account.